SEDIMENT EQUILIBRIUM ESTIMATES FOR THE REVISED FEASIBILITY STUDY

As part of the Portland Harbor Superfund Site (Site) Feasibility Study (FS) revision process, the U.S. Environmental Protection Agency (EPA) and the Lower Willamette Group (LWG) have discussed the difference between "background" (i.e., upstream bedded sediment concentrations as presented in the Remedial Investigation [RI]) and the concept of "equilibrium" conditions for the Study Area (i.e., potential future bedded sediment concentrations within Portland Harbor). Using equilibrium values is a better approach for the revised FS because those values more closely represent the pertinent conditions for the Site as described more below. On June 19, 2014, the LWG provided a general proposal for establishing and using equilibrium concentrations in the revised FS (Attachment 2 of "LWG Comments on Revised FS Section 2"). This memorandum provides additional specific estimates of Study Area equilibrium concentrations to be used in the revised FS.

The June 19, 2014 proposal describes the equilibrium concept and proposes a general approach for estimating equilibrium values. In summary, the RI and FS conceptual site model (CSM) indicates a large input of sediment into the Study Area from the upstream watershed causing current Study Area bedded sediment Surface Weighted Area Concentration (SWACs) to decrease over a variety of Study Area spatial scales and areas to a lower equilibrium level. The equilibrium is the result of incoming settling sediment input to the sediment bed, which is controlled by the concentrations of contaminants in the incoming sediments from upstream. Active remediation of the Study Area cannot achieve concentrations lower than that of the equilibrium level. This element of the CSM was confirmed by suspended sediment, sediment trap and other types of sampling data as well as hydrodynamic and sediment transport analyses conducted for the RI and FS.

The equilibrium conditions are the best estimate of the lowest contaminant of concern (COC) concentrations that can be achieved by remediation in the Study Area. For example, in the Lower Duwamish Waterway (LDW) Proposed Plan (EPA 2013a) several datasets representing COC concentrations in suspended sediments entering that site from the upstream Green/Duwamish River system were evaluated because they represent "future COC concentrations in the LDW after implementation of cleanup alternatives" (p.26). This included the use of deposited sediments in an upper turning basin, because "these data provide an indicator of suspended sediments settling within the upper reach of the LDW"(p.27).

The equilibrium concept is a critical consideration in evaluating the long-term effectiveness of remedial alternatives in the FS. EPA guidance provides that PRGs should be achievable by the remedy: "The project manager may discuss these other actions in the ROD [Record of Decision] and explain how the site remediation is expected to contribute to meeting area-wide goals outside the scope of the site, such as goals related to watershed concerns, but Remedial Action Objectives (RAOs) should reflect objectives that are achievable from the site cleanup" (EPA 2005). For example, the Grasse River ROD (EPA 2013b, p. 54) indicates, "The selected remedy will comply with all of the listed ARARs in Tables 13-1 through 13-3 except two chemical-specific ARARs which are not expected to be met due to Site background PCB loading conditions. Therefore, because of technical impracticability, those two ARARs are being waived."

Regional 'background' concentrations are based on bedded sediment conditions that differ from the Study Area and are upstream of important anthropogenic sources of COCs in the Portland metro area. These 'background' concentrations do not represent achievable equilibrium conditions that affect post-remedy conditions within the Study Area. The proposed approach to estimate Study Area equilibrium levels is to use a combination of the following lines of evidence:

- Existing RI/FS empirical data
  - Deposited surface sediment data
    - Data from depositional areas upstream of the Study Area boundary
    - Data from depositional areas within upper portions of the Study Area away from known Study Area sources
  - Sediment trap data
  - Upstream suspended sediment data
  - Smallmouth bass fish tissue data from 2002, 2007, and 2011/12 (available for polychlorinated biphenyls [PCBs] only)
- Model projections using the coupled QEAFATE and dynamic Food Web Model (FWM)

In this memorandum, specific methods and estimates for total PCBs and total 2,4′ and 4,4′-DDD, -DDE, -DDT (DDx) equilibrium levels are presented. Once the LWG and EPA agree on specific estimation methods, similar estimates would be calculated for the other Remedial Action Level (RAL) chemicals (i.e., dioxin/furans and benzo(a)pyrene equivalent) using the same data sources and methods. The next section summarizes the LWG-proposed equilibrium estimates for use in the revised FS. The subsequent sections provide details on the rationale and calculation of the proposed estimates.

PROPOSED FEASIBILITY STUDY EQUILIBRIUM ESTIMATES

The LWG proposes overall equilibrium estimates based on sediment empirical data of:

- 20 micrograms per kilogram (µg/kg) for total PCBs
- 5 µg/kg for total DDx

These estimates represent reasonable upper confidence limits (UCLs) on a central tendency (median) of the empirical sediment lines of evidence (i.e., deposited surface sediment data, sediment traps, and suspended sediments). These estimates are corroborated by empirical fish tissue equilibrium estimates for PCBs. They are further corroborated by draft FS model projections, which bracket the empirical central tendency estimates for both contaminants.

The LWG recommends that these equilibrium central tendency estimates be used in the revised FS for the following purposes:

- Preliminary Remedial Goal (PRG) selections (Section 2 of the revised FS) – Risk-based PRGs below these central tendency equilibrium estimates should not be selected by EPA and, instead, the equilibrium central tendency should be used for the PRG. This is consistent with EPA guidance on the selection of PRGs relative to background conditions (EPA 2002a) and setting RAOs for sediment remedies that are achievable (EPA 2005).
- SWAC calculations (Sections 3 and 4) – The central tendency equilibrium estimates should be used as the "replacement" value in any calculations estimating SWACs immediately after active remediation or similar SWAC estimates.
- The detailed evaluations of alternatives (Section 4) – The central tendency equilibrium estimates should be used to represent the lowest long-term sediment concentrations that are reasonably achievable by any remedial alternative.

For all of these purposes, the revised FS should include an explicit discussion and presentation of the range of equilibrium estimates based on all lines of evidence so that the uncertainties associated with the recommended central tendency estimates can be understood and factored into remedy selection decisions.

The following sections detail the calculation and rationale for these proposed estimates.

PART 1 - EMPIRICAL LINES OF EVIDENCE

An evaluation of the quality of sediment entering the Study Area at its upstream boundary (river mile 11.8) based on available empirical data was presented in the draft final RI, dated August 29, 2011 (Appendix H and Section 7.5). The analyses presented in the draft final RI and used in this section include the following:

- Deposited surface sediment from the Up-river Reach (above river mile 15.3)
  - Note that this dataset is more extensive than the background dataset used in the RI. The RI background analysis only utilized data of the highest quality assurance level (Cat 1 QA2); the analysis described here also includes a subset of Cat 1 QA1 data.
- Deposited surface sediment from the Downtown Reach (between river miles 11.8 and 15.3)
  - Note that this dataset excludes all samples associated with the Zidell site sampling events.
- Deposited surface sediment from the upstream end of the Study Area (locations G486, G483, G734, G745-1, G745-2, G466, and RC483-2; shown in draft final RI Map 2.2-1m)
  - Similar to the borrow pit cores listed below, these stations were situated on a natural depositional shoaling area (see draft final RI Map 3.1-7) and away from any known sources of DDx or PCBs.
- Borrow pit ("natural" sediment trap) surface and subsurface sediment samples from the Study Area (locations RC01-2, RC01-2)
- Data from (deployed) sediment trap locations both within and upstream of upper Study Area: ST008 (river mile 11.5W), ST010 (river mile 15.6W), and ST090 (river mile 15.7)

  - Data from the sediment trap at river mile 11E (ST007) was excluded from this data compilation due to the known source of PCBs at river mile 11E.
- Particulate surface water samples from all river mile 16 and river mile 11 sampling events
  - As with the sediment traps, PCB data from river mile 11 were excluded due to the known source of PCBs at river mile 11E.

These data for total DDx and total PCBs are generally summarized in Table 1. The total DDx and total PCB concentrations were generated for bedded sediment per the risk assessment summing rules; as such, they are directly comparable to the values presented in the background section (Section 7) of the RI. In addition, smallmouth bass tissue empirical data are available and are discussed following the sediment lines of evidence below.

Statistical Methods

Central tendency and upper percentiles statistics are two useful values to describe empirical chemical concentrations in different sediment sources contributing to current and future equilibrium conditions. They are standard statistics for evaluating environmental sample data (Zar 2010; Helsel and Hirsch 2002) and are commonly used to evaluate “background” conditions (EPA 2002a). Based on the amount and variance of sample data, a range of known confidence around the central tendency or percentile estimate of the sampled population can be determined (Cochran 1977; Zar 2010).

The empirical sediment datasets used to characterize equilibrium conditions are subject to natural variation such as stream flow or rainfall duration and magnitude. Given the potentially dynamic nature of these sediment sources, the variance may be relatively high, and data may exhibit a right skewness with higher magnitude concentrations (Helsel and Hirsch 2002). As such, statistical estimates of central tendency must be selected to account for the distributional characteristics of the sample data. Although upper percentile estimates are appropriate for use in evaluating equilibrium conditions, statistics for the 75th percentile or greater may be sensitive to the influence of values near the upper tail of the distribution (Helsel and Hirsch 2002). Another consideration is that equilibrium sediment concentration estimates should be relevant to the spatial scales associated with exposure areas of a risk-based sediment remediation. Many potential risks found in the baseline risk assessments were assessed over large portions of or even the entire Study Area (e.g., human health fish consumption). For remediation activities relevant to these large spatial scale assessments (e.g., selection of PRGs relative to achievable long-term sediment concentrations), upper percentile estimates may be less appropriate because they are unduly influenced by high values near the tail of the distribution.

Of the central tendency statistics, the mean may also be influenced by values at the upper or lower range of the distribution, similar to percentile estimates (Zar 2010; Helsel and Hirsch 2002). The median (i.e., the typical value) provides a “resistant” statistic for describing equilibrium conditions in that the median is only minimally affected by the magnitude of a single observation, being determined solely by the relative order of observations (Helsel and Hirsch 2002). For this reason, the median was selected as the statistic to characterize the individual empirical lines of evidence for evaluating equilibrium conditions. Interval statistics (i.e., confidence intervals) were calculated on the median for each empirical line of evidence. Interval statistics are most appropriate if the center of mass of the data, like the median, is the statistic of interest (Helsel and Hirsch 2002).

All of the empirical lines of evidence contribute to an understanding of equilibrium conditions. Therefore, for each empirical line of evidence, the 95% UCL on the median was calculated. This is the value where one is 95% certain that the median of the population is not any higher (Helsel and Hirsch 2002). The median of all the 95% UCL on the median values for the different lines of evidence was then computed. This quantity conceptually represents the central tendency of concentrations of upstream watershed sources that would contribute to equilibrium concentrations such that a distribution of hypothetical future samples collected at the Study Area across appropriate spatial and temporal scales would approximate the same estimate of central tendency.

For each line of evidence, the 95% UCL on the mean was also calculated for comparative purposes, but the 95% UCL on the median is the primary focus of this analysis.

The use of a central tendency statistic that is based on the best-fit distribution of the data is a standard statistical approach for evaluating chemical concentrations in the environment (Zar 2010; Helsel and Hirsch 2002). As such, goodness-of-fit tests were first performed to determine which distribution to assume for computing the 95% UCL on the median and 95% UCL on the mean. Distributions were tested in the following order: normal, gamma, then log-normal distribution. If a test did not reject the assumed distribution, that distribution was used to compute the UCLs. If the normal distribution was rejected, the gamma distribution was tested before the log-normal distribution because the gamma distribution is less sensitive to high magnitude values and small sample sizes than the log-normal distribution (Singh et al. 2002).

When the data fit no established mathematical distribution, a non-parametric method was selected to calculate the UCLs. Non-parametric statistics are based on the ranks of the data and, therefore, are less influenced by high magnitude values. They are a common method for calculating statistics for environmental datasets that do not fit established distributions (Zar 2010; Helsel and Hirsch 2002). The non-parametric UCL for the median is computed based on the binomial distribution, sample size, and desired level of confidence (Schwarz 2011). For a given sample size, a particular order statistic greater than the sample median is chosen as the UCL for the population median, and the associated confidence level is determined. The order statistic is chosen so that the associated confidence level is at least as large as the desired confidence level. For determining the non-parametric 95% UCL on the mean, the 95% UCL was calculated by applying the Chebyshev inequality (Singh et al. 1997), which is consistent with EPA (2002b) guidance for selecting non-parametric statistics for moderately skewed data.

For the purpose of evaluating the distribution of the data and calculating the appropriate statistic for the 95% UCL on the median, EPA ProUCL (Version 5.0) software was used. The selected calculation method and resulting statistics are provided in Table 2. In addition to the 95% UCL on the median, Table 2 reports for reference the mean, median, maximum, standard deviation, and coefficient of variation as well as the 95% UCL on the mean.

For PCBs, two different analytical or summation methods available in the database were examined: total PCB congeners (calculated) and total PCB Aroclors (calculated). Both methods were calculated following the data summing rules for the BERA, which was also the approached used and defined in the revised RI Section 7. Table 1 summarizes PCB data based on the total PCB Aroclors method except in the case of suspended sediments, which is based on total PCB congeners because they are the only data available for this line of evidence. Because total PCB Aroclors, with the use of total PCB congeners for suspended sediment, provide the largest sample sizes and best overall coverage of data across all lines of evidence, this approach was the focus of PCB statistics and discussion presented here. However, for comparative purposes, statistics based on total PCB congeners are also presented (Table 2).

Because the 95% UCL on the median is appropriate for large spatial scale comparisons, for reasons discussed above, we propose that this statistic be used where unacceptable risk exposure areas being assessed in the FS are for larger spatial scales. Thus, this statistic is most appropriate for Site-wide comparisons and is not suitable for small spatial scale comparisons. For smaller spatial scales, an upper range statistic should be considered instead, such as plus one standard deviation or an upper percentile (e.g., 75th percentile or above). Where comparisons to equilibrium estimates over smaller spatial scales are necessary and technically appropriate for the revised FS, additional assessment of the empirical data will be conducted in coordination with EPA to specify appropriate equilibrium values for such smaller spatial scale comparisons.

Deposited Surface Sediment

Deposited surface sediment in areas not impacted by localized sources upstream of the Study Area and at the upper end of the Study Area is a good indication of ongoing equilibrium concentrations supported by suspended sediment loads moving through the river system. Variations would be expected based on the actual depositional dynamics in any given sample area. To help assess these variations, deposited sediment from the three reaches was examined:

- Upriver Reach above river mile 15.3
- Downtown Reach between river miles 11.8 and 15.3 excluding Zidell data
- Upstream portions of the Study Area away from known localized sources

The statistical methods described above were applied to calculate the 95% UCL on the median for deposited sediment data from these three reaches. Table 2 presents the summary statistics for deposited sediment for each reach. Total DDx data distributions varied for the three reaches (i.e., gamma, normal, and non-parametric). Total PCB Aroclor distributions were all non-parametric and the 95% UCL on the median was computed as such.

For total DDx the 95% UCL on the median ranges from 2.1 to 4.9 μg/kg across the three reaches. For total PCB Aroclors this statistic ranges from 8.6 to 22.3 μg/kg.

Deposited surface sediment sample sizes for total PCB Aroclors were much greater than for total PCB congeners in all of the reaches examined, which supports the use of the total PCB Aroclors method as the best approach to estimating equilibrium for PCBs. (Note that while the total PCB congeners data from river miles 11.8 to 15.3 were determined to be approximately normal, because of the small sample size and the fact that the 95% UCL on the median is an order of magnitude higher than the median itself, the non-parametric estimate of 197.2 μg/kg is likely more reliable [Helsel and Hirsch 2002]).

Sediment Trap Data

The contaminant concentrations in the deposited material within sediment traps and in the former borrow pits (which act as natural sediment traps) are good indicators of material available to deposit on sediment surfaces within the Study Area. Although deployed sediment traps do not directly measure deposition onto bedded sediments, understanding the concentrations in material available for deposition provides a good indication of the eventual equilibrium levels where deposition consistently occurs. In the case of the natural sediment traps, these actually directly measure sediment deposition in one type of depositional area (i.e., the borrow pits).

Deployed sediment traps were sampled in four quarters during 2007; thus, the measurements are specific to that year and some variations over years would be expected. However, the available sediment trap data fall into a similar range as the other equilibrium measures (Table 2). This suggests that 2007 was a relatively typical year that can be used to extrapolate to a wider timeframe.

Two high resolution cores were collected in the upper portion of the Study Area in areas near river miles 10 to 11 from two former dredge borrow pit areas excavated in approximately 1988. These areas functioned as effective sediment traps (i.e., 15 to 25 feet of deposition occurred below the authorized navigation depth over the 19 years following dredging; Anchor Environmental 2007). Because of the high sediment trapping efficiency of this area, the 2007 sediment core results provide a good representation of concentrations of material settling here throughout this period. The variations in the observed contaminant concentrations across depths in the cores were relatively minor indicating consistency in the settling sediment inputs over the years of deposition (see Figure H4.1-9 and H4.1-11 of the draft final RI).

The statistical methods described above were applied to the calculation of 95% UCL on the median for the sediment trap data; Table 2 presents the summary statistics. There were ten sediment trap samples. All distributions of the contaminant totals were normal or log-normal and all 95% UCL on median statistics were computed using parametric methods.

Upstream Suspended Sediment

Another way to evaluate potential equilibrium conditions is to examine suspended sediment in the water column from upstream of the Study Area. Like deployed sediment traps, this is an indicator of available source material contributing to depositional equilibrium over time. Also like sediment traps, the water column samples were collected over a specific range of flow conditions in the years sampled. The similarity in concentrations across the various lines of evidence (Table 2) suggests that the surface water sampling events taken together were relatively typical. Water column samples collected at river miles 11 and 16, for which contaminant concentrations were measured in both particulate and dissolved phases, were assessed. These data were used to calculate the chemical concentrations on suspended sediment particles (see Section 6.2.2 of the draft FS). Suspended sediment data can be separated into two groups based on flow conditions in the river (low flow and high flow). The majority of sediment loading to the Study Area occurs during high flow conditions, but the contaminant concentrations in suspended sediments are generally higher during low flow (draft FS Section 6.2.2).

The statistical methods described above were applied to the calculation of 95% UCL on the median for the upstream suspended sediment data; Table 2 presents the summary statistics. The total DDx data were gamma distributed and the total PCB Arcolor data were normally distributed, and 95% UCLs on median statistics were computed as such.

Summary of Sediment Chemistry Empirical Lines of Evidence for Evaluating Equilibrium

Comparing the 95% UCLs on the median across the three empirical lines of evidence (deposited sediments, sediment traps, and suspended sediment), the values for this statistic were generally very similar for both total DDx and total PCB Aroclors. More specifically, the sediment trap values for both contaminants were slightly higher than the deposited sediment values, while the suspended sediment value was somewhat higher than the other two lines of evidence for total DDx.

Because all of the sediment empirical lines of evidence contribute to an understanding of equilibrium conditions, the median of the individual lines of evidence was selected as the combined line of evidence that represents appropriate spatial and temporal scales of the receiving environment relative to remediation activities. The individual and combined lines of evidence for evaluating equilibrium condition sediment chemistry concentrations are summarized in Table 3. For additional context, it is noteworthy that the total PCBs Table 3 result for Upstream Deposited Sediment from RM 11.8 to 15.3 of 22.3 µg/kg is very similar to the bedded sediment concentration estimate of 28 µg/kg made by Oregon Department of Environmental Quality for this same river reach (DEQ 2011).

PART 2 - SMALLMOUTH BASS TISSUE PCB CONCENTRATIONS

Smallmouth bass tissue concentrations were sampled for PCBs in 2002 and 2007 for the RI and then again in 2011 and 2012 by EPA and the LWG, respectively. Tissue samples were collected both from within the Study Area (in all years) and upstream of the Study Area (in 2002 and 2011/2012). Study Area tissue concentrations have shown a statistically significant decline between 2002/2007 and 2011/2012 (Anchor QEA 2013). As a result, 2011/2012 tissue concentrations from some portions of the Study Area (e.g., away from areas of elevated sediment concentrations and known localized sources) are very similar to upstream tissue sample concentrations, and provide an indication of likely equilibrium levels in fish tissue. Similarly, upstream tissue samples provide data distant from any Study Area sediment impacts and upland sources, which indicates potential Study Area equilibrium levels once Study Area sediment remediation and source controls are completed.

The measured sediment concentrations associated with areas of low tissue concentrations either within the Study Area or upstream, provide a direct indication of potential sediment equilibrium levels. Also, tissue equilibrium concentrations can be converted into sediment concentrations over broad areas of the Study Area using the coupled QEAFATE model and dynamic FWM. These models are calibrated to current conditions (i.e., the FS database) in terms of surface water, sediment, and tissue data. Although there is some uncertainty with model extrapolations from tissue to sediment concentrations, this uncertainty can be specifically addressed through examination of modeling uncertainty bounds (presented in the draft FS) and by comparison to the sediment empirical lines of evidence discussed above.

Figure 1 shows the locations of tissue samples collected within the Site, groups of 2002 and 2007 tissue samples that were used for the statistical comparisons noted above (Anchor QEA 2013), and PCB sediment concentration contours. Average tissue and sediment PCB concentrations by half river mile and from up-river areas are shown in Table 4. The blue highlighted cells in Table 4 represent Study Area tissue PCB averages that are relatively low and come from Study Area regions that also have relatively low PCB sediment concentrations. (Examining all data as averages by half river mile, the blue highlighted cells in Table 4 were specifically defined as Study Area tissue PCB averages from 2011/2012 that are below the median of the Study Area averages and are from areas that are below the median SWACs shown in Table 4.)

The sediment concentrations were examined in areas where the PCB average tissue concentrations from the 2011/2012 Study Area data were low (as defined above and highlighted in Table 4), up river for 2012 samples from river miles 15 through 18, and up river for 2002 samples from river miles 21 through 24.

The median sediment concentration (median of half river mile SWACs) from portions of the Study Area with low tissue concentrations was 35 µg/kg. The arithmetic average sediment concentration in 2012 samples from river miles 15 through 18 was 50 µg/kg, and the arithmetic average sediment concentration from 2002 samples from river miles 21 through 24 was 12 µg/kg. Because the site sediment median is a SWAC-based estimate, and the upstream statistics are arithmetic averages, they are not strictly comparable. (SWAC-based upstream estimates are not readily available.) Nonetheless, the upstream arithmetic averages provide an approximate central tendency for general comparison to the Site SWAC central tendency.

Also, although half river miles were a useful spatial scale for identifying the above Study Area correlations between sediment and tissue PCB concentrations, it is important to note that this spatial scale was used for data analysis purposes only. The existence of a correlation using certain assumptions (spatial scales in this case) does not indicate causality between the assumptions used and the resulting correlation. Based on the approved risk assessments, it is known that smallmouth bass can range over larger spatial scales and the human health exposures (people catching fish) can range over even larger spatial scales. Consequently, the half-river mile spatial scale is not a risk-based determination and should not be extrapolated to risk-based assessments (e.g., revised FS assessments of remedial alternatives performance). Further, the actual statistic of interest here is the median across all low concentration half river miles, which represents a substantial portion of the entire Site. Thus, this median value is most appropriate for use in Site-wide comparisons, similar to the sediment empirical data median statistics.

PART 3 - MODEL PROJECTIONS USING THE COUPLED QEAFATE AND DYNAMIC FOOD WEB MODEL

Study Area-wide QEAFATE contaminant fate and transport modeling was conducted as part of the draft FS (Appendix Ha) to evaluate the short- and long-term effectiveness of alternatives including the no action alternative. The model was parameterized with the empirical data described above (in addition to many other types of Study Area data). The model provides a comprehensive framework to project the impact of incoming sediment contaminant concentrations on Study Area bedded sediments in a consistent manner that ensures conservation of mass. Similarly, the modeling allows consistent assessments of the spatial and temporal variability of deposition and other key processes (e.g., erosion, flow dynamics). While modeling is not intended to substitute for the empirical data analysis presented above, it provides additional perspective on Study Area equilibrium levels including potential spatial variations and how long it may take to achieve those levels. The model runs discussed below were performed for the draft FS and were not specifically performed for this evaluation or feed directly into the conclusions of this document. However, the modeling information from the draft FS provides confirmation of the empirical data evaluation presented above.

Figures 2 and 3 show the Study Area-wide model projections for the various draft FS alternatives for total PCBs and total DDx.

For the no action alternative, long-term Study Area-wide surface sediment concentrations in 45 years were projected to reach an equilibrium of the following:

- 29 to 48 µg/kg for total PCBs
- 3 to 16 µg/kg for total DDx

These ranges take into account the uncertainty analysis conducted for the modeling, which is described in more detail in the draft FS. Figure 2 shows Site-wide model results for the primary or "baseline" modeling runs. (The model results were also presented on smaller spatial scales, such as river miles, in the draft FS.)

In comparison, for Alternatives B through F (involving active remediation and as defined in draft FS Section 7), long-term Study Area-wide surface sediment concentrations in 45 years were projected to reach an equilibrium of the following:

- 8 to 28 µg/kg for total PCBs
- 3 to 27 µg/kg for total DDx

Again these ranges include model uncertainty analyses, while Figure 2 shows the baseline modeling runs.

Cap recontamination modeling conducted in the draft FS on a smaller spatial scale provides another perspective on long-term equilibrium levels that assists in examining spatial variability across the Study Area. Using the same comprehensive modeling framework, the draft FS modeled the likelihood and degree of concentration changes in several areas (usually several acres in size) where clean caps were assumed to be placed. The surface sediment concentration immediately after capping was assumed to be zero for each contaminant modeled.

Figures 4 and 5 show the draft FS results of this modeling for total PCBs and total DDx over the capping portions of several SMAs. Due to long-term incoming sediment deposition, all the cap areas were projected to return after construction to surface sediment concentrations of the following:

- 8 to 25 µg/kg for total PCBs
- 1 to 20 µg/kg for total DDx

These ranges represent variations across the different small capping areas of the Study Area that were examined and show some of the spatial variability that would be expected with Study Area equilibrium levels. It also shows that the system will trend toward the new equilibrium levels in both actively remediated areas (upward trend) as well as natural recovery areas (downward trend).

The model-projected ranges all bracket the 95% UCL on the median for the sediment empirical lines of evidence for PCBs of 20 µg/kg and for DDx of 4.9 µg/kg (Table 3). The model projections also closely approximate the average total PCB sediment concentrations from areas of low tissue concentrations (as defined above) in the Study Area and upstream, which ranged from 12 to 50 µg/kg. This demonstrates overall good corroboration between the empirical lines of evidence and the modeling projections from the draft FS.

CONCLUSIONS

Similar to determinations at other sites (e.g., Duwamish), equilibrium conditions are the best estimate of the lowest contaminant concentrations that can be achieved by remediation in the Study Area. Given that EPA guidance clearly provides that PRGs should be achievable by the remedy, the equilibrium concept is a critical consideration in evaluating the long-term effectiveness of remedial alternatives in the FS. For evaluating alternative effectiveness, equilibrium estimates are superior to regional ‘background’ estimates because upstream bedded sediment and source conditions differ substantially from the Study Area.

The LWG proposes overall equilibrium estimates using the 95% UCL on the median of sediment empirical data (i.e., deposited surface sediment data, sediment traps, and suspended sediments) for total DDx and total PCBs. These estimates are corroborated by empirical fish tissue data for total PCBs. They are further corroborated by draft FS model projections, which bracket the empirical central tendency estimates for both contaminants.

These equilibrium estimates should be used for multiple purposes in the revised FS including PRG comparisons, SWAC calculations, and the detailed evaluations of alternatives. For all of these purposes, there should also be explicit discussion and presentation of the range of equilibrium estimates, including the appropriate spatial scale comparisons, based on all lines of evidence so that the uncertainties associated with the recommended central tendency estimates can be understood and factored into remedy selection decisions.

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Table 1. Summary of Available Data Related to Sediment Contaminant Concentrations Entering the Study Area.

Analyte	Line of Evidence	Valid N	Concentration (µg/kg) Mean	Median	Minimum	Maximum
Total DDx	Deposited Sediment in Upper Portions of Study Area[a]	34	4.35	4.40	0.88	11.0
	Deposited Sediment between RMs 15.3 and 11.8[b]	155	6.63	3.36	0.13	73.3
	Deposited Sediment above RM 15.3[c]	83	2.30	1.90	0.13	14.6
	Upstream Sediment Traps[d]	10	5.01	4.67	2.50	7.35
	Incoming Suspended Sediment[e]	17	13.3	8.30	1.71	65.3
Total PCB Aroclors	Deposited Sediment in Upstream Portions of Study Area[a]	34	13.1	7.50	2.50	31.0
	Deposited Sediment between RMs 15.3 and 11.8[b]	156	49.6	20.0	0.73	712
	Deposited Sediment above RM 15.3[c]	83	11.5	7.10	1.00	53.0
	Upstream Sediment Traps[d]	10	42.8	6.90	3.10	310
	Incoming Suspended Sediment[e,f]	7	9.01	9.23	1.56	24.6

Notes:

[a] Stations G486, G483, G734, G745-1, G745-2, G466, and RC483-2 situated on a natural shoaling area away from any known sources of DDx or PCBs.

[b] Excluding Zidell data and sample G048 (RM 13.1) with a total PCB Aroclor concentration of 4,216 µg/kg.

[c] Including both Cat 1 QA2 and Cat 1 QA1 data.

[d] Borrow pit “natural” sediment trap stations RC01-1 and RC01-2 and deployed sediment traps ST008 (RM 11.5W), ST010 (RM 15.6W), and ST090 (RM 15.7). Data from the sediment trap at RM 11E (ST007) not included.

[e] Particulate surface water samples from all RM 16 and RM 11 sampling events. PCB data from RM 11 were excluded.

[f] Suspended sediment data are total PCB congeners; no Aroclor data were available.

DDx - 2,4′ and 4,4′-DDD, -DDE, -DDT
N - number of samples
PCB - polychlorinated biphenyl
RM - river mile

Table 2. Summary Statistics for Sediment Empirical Lines of Evidence for Study Area Equilibrium Conditions for DDx and PCBs.

Chemical Sum	Parameter	Sediment Traps	Suspended Sediment	Deposited Sediment from River Miles 11.8 to 15.3	Deposited Sediment from Above River Mile 15.3	Deposited Sediment from Upstream Portions of Study Area
Total DDx (calc'd)	Distribution	Normal	Gamma	Gamma	No distribution - non-parametric	Normal
	Sample Size	10	17	154	83	34
	Mean	5.0	13.3	6.2	2.3	4.4
	Median	4.7	8.3	3.1	1.9	4.4
	Maximum	7.3	65.3	73.0	14.6	11.0
	Standard Deviation	1.7	15.1	9.2	2.1	1.9
	Coefficient of Variation	33%	114%	148%	93%	44%
	95 UCL on Mean	6.0	21.2	7.3	3.3	4.9
	95% UCL on Median	5.9	14.1	4.1	2.1	4.9
Total PCB Congeners (calc'd)	Distribution	Normal	Normal	Normal	No distribution - non-parametric	NA
	Sample Size	10	7	8	27	1
	Mean	7.3	9.0	229.9	4.7	NA
	Median	6.2	9.2	45.9	3.0	NA
	Maximum	13.2	24.6	912.0	31.0	NA
	Standard Deviation	3.1	8.4	343.3	6.9	NA
	Coefficient of Variation	43%	94%	149%	147%	NA
	95 UCL on Mean	9.1	15.2	459.9	10.4	NA
	95% UCL on Median	9.0	15.0	452.2[a]	3.4	NA
Total PCB Aroclors (calc'd)[b]	Distribution	Log-normal	Normal	No distribution - non- parametric	No distribution - non-parametric	No distribution - non-parametric
	Sample Size	10	7	156	83	34

Chemical Sum	Parameter	Sediment Traps	Suspended Sediment	Deposited Sediment from River Miles 11.8 to 15.3	Deposited Sediment from Above River Mile 15.3	Deposited Sediment from Upstream Portions of Study Area
	Mean	42.8	9.0	49.6	11.5	13.1
	Median	6.9	9.2	20.0	7.1	7.5
	Maximum	310.0	24.6	712.0	53.0	31.0
	Standard Deviation	94.8	8.4	95.1	12.6	10.1
	Coefficient of Variation	222%	94%	192%	109%	77%
	95 UCL on Mean	173.4	15.2	82.8	17.5	20.7
	95% UCL on Median	27.5	15.0	22.3	8.6	20.0

Notes:
All units are micrograms per kilogram (µg/kg).

[a] Non-parametric value of 197.2 is considered more reliable. See text.
[b] Suspended sediment based on total PCB congeners.

DDX - 2,4′ and 4,4′-DDD, -DDE, -DDT
NA - data not available
PCB - polychlorinated biphenyl
UCL - upper confidence limit

Table 3. Summary of Sediment Empirical Lines of Evidence for Evaluating Equilibrium Conditions (µg/kg).

Contaminant	Individual Sediment Empirical Lines of Evidence					Recommended Combined Line of Evidence
	Sediment Trap	Upstream Suspended Sediment	Upstream Deposited Sediment RM 11.8 to 15.3	Upstream Deposited Sediment above RM 15.3	Deposited Sediment in Upstream Portion of Study Area	
Total DDx	5.9	14.1	4.1	2.1	4.9	4.9
Total PCBs Aroclors[a]	27.5	15.0	22.3	8.6	20.0	20.0

Notes:

Individual empirical lines of evidence are the 95% upper tolerance level on the median, as described in the text and presented in Table 2. The combined line of evidence is the median of the individual empirical lines of evidence.

[a] Suspended sediment is based on total PCB congeners.

µg/kg - micrograms per kilogram
DDx - 2,4′ and 4,4′-DDD, -DDE, -DDT
PCB - polychlorinated biphenyl
RM - river mile

Table 4. Average Smallmouth Bass Tissue Concentrations (µg/kg ww) and Sediment SWACs (µg/kg dw) by Study Area Half River Mile and Up River Areas.

Half RMs	Total PCB Sediment SWAC	Average Tissue Total PCB Concentration		
		2002	2007	2011/2012
2-2.5	121		1420	486
2.5-3	27		243	457
3-3.5	20	935		478
3.5-4	78	629	1460	417
4-4.5	51		288	269
4.5-5	29		270	182
5-5.5	22	417		221
5.5-6	38	344		236
6-6.5	33		478	298
6.5-7	109	517	2,010	275
7-7.5	49	549	536	235
7.5-8	37	663	289	233
8-8.5	40	748	454	426
8.5-9	110		967	623
9-9.5	96		349	262
9.5-10	57		718	787
Swan Is.	670	3025		447
10-10.5	56			214
10.5-11	41		531	428
11-11.5	145		6,600	2,379
11.5-12	34			453
Up River (15-18)	50[a]			234
Up River (21-24)	12[a]	238		

Notes:
[a] Average of dataset (not a SWAC).

Color indicates tissue averages that are below the Study Area 2011/12 tissue median from half river miles that are below the Study Area sediment SWAC median.

µg/kg dw - micrograms per kilogram dry weight
µg/kg ww - micrograms per kilogram wet weight
PCB - polychlorinated biphenyl
RM - river mile
SWAC - Surface Weighted Area Concentration